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ABSTRACT

A quality control model is proposed to facilitate development of effective instructional programs. The theories of R. M. Gagne and of M. D. Merrill provide the foundations for a theory of sequencing behavior into a hierarchical order in order to improve the learning potential of an instructional program. The initial step in the procedural model is to identify the enabling objectives which allow performance of the terminal objective. After these objectives are identified and hierarchically charted, the sequence is validated by a task analysis. An evaluation by individuals for whom the program is designed should eliminate ambiguous directions. The next step in the model is an empirical validation of the entire program to determine if the student reaches the terminal objective successfully and if the sequencing is effective and efficient. Finally the program is revised according to the results obtained in the preceding step and recycled until an acceptable criterion is reached. (JY)

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INSTRUCTIONAL RESEARCH AND DEVELOPMENT

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A QUALITY CONTROL DESIGN FOR VALIDATING HIERARCHICAL SEQUENCING OF PROGRAMED INSTRUCTION

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With the inception of programed instruction as a serious pursuit by psychologists and educators, the problem of sequencing subject matter has been chronic. Early efforts to demonstrate the superiority of various schemes for determining optional sequences have been disappointing. Research findings do not generally differentiate between the effectiveness of an ordered sequence over a random sequence.

Sequencing seems to be complicated by two factors: the failure to recognize that conditions of learning appropriate to one task are not appropriate to another; and inadequate methods of empirically validating programs.

In Conditions of Learning, Gagné (1965, 1970) stated the eight conditions of learning as: signal learning, stimulus-response learning, chaining, verbal association, discrimination learning, concept learning, rule learning, and problem solving. Gagné's hierarchy is the first model to bridge basic learning theory and the more applied concerns of instructional psychologists. By discussing the conditions

necessary for learning, Gagné enabled translation of essential conditions into manipulated instructional strategy for maximally efficient and effective learning. Gagné's initial book (1965; second edition, 1970), and his papers (1967, 1968) have influenced educational technologists to change focus from attempts to adapt abstract learning theory to the development of instructional theories based on a hierarchical sequence. Gagné asked the question, "Is there a sequence of forms of learning, from simple to complex, that should be followed in instruction?" (1965, p. 179). He answered affirmatively, and continued his discussion by insisting that there needs to be a method of deciding "what is to be learned before what." His hierarchy developed on the premise that each level of learning requires a unique condition and that a differing form of external situation is needed for each behavior.

However, Gagné has failed to separate learning hierarchy from logical hierarchies. The identification of hierarchical conditions is not arbitrary. I. e., problem solving behavior depends on analysis behavior; which depends on classification behavior; etc., down the hierarchy of prerequisites. This contrasts with a logical hierarchy where the subject matter dictates the sequence and is assumed to exist in a hierarchy of conditions. An example of a Gagné logical hierarchical flow chart which calculates factor numbers into prime numbers written

in exponential form is Figure 1. This chart represents the usual procedure of outlining the subject matter on a supposed logical sequence determined by a subject matter expert who assumes that to reach the terminal objective a person would have to be taught according to the flow of the arrows. The terminal behavior (Fig. 1) represents problem solving preceeded by rules and concepts.

Insert Figure 1 about here

A learning hierarchy is sequenced according to conditions of behavior not subject matter. Complex subject matter is not appropriate as a sequencing method because it fails to follow consistent order. Behavioral levels, on the contrary, can accept various orders of subject matter because they are controlled by differing instructional processes which are dependent upon the behavior required. Merrill's paradigm of instruction (Fig. 2) does provide a learning hierarchy using levels of behavior.

Insert Figure 2 about here

Emotional behavior is assumed to apply at all levels of instruction, and is placed at the top of the model. The hierarchical structure is based upon the presumption of essential prerequisite conditions moving from the lowest level of instruction, psychomotor, to the highest com-

plex cognitive. Within each level the sequence moves from left to right in a simple-to-complex structure. Each level corresponds vertically in component definitions; e. g., chaining behavior, serial behavior, and analysis behavior are a series of single responses learned in the previous condition.[1] The behaviors required on the complex cognitive level are: classification behavior requires that a student identify correctly previously unencountered instances of a concept class; analysis behavior requires that a student demonstrate the functional relationship of the component concepts of a principle in an unencountered situation; problem solving behavior requires a student to analyze several principles and synthesize a strategy for solution.

Analysis behavior, for example, differs from Gagné's rule learning in that Merrill is concerned with the students use of the principle, whereas, Gagné is concerned with identifying components of the principle. The difference between the logical hierarchy (Fig. 1) which is subject matter controlled, and a learning hierarchy which is controlled by behavior, is Figure 3. In both cases the hierarchy must be validated prior to correct sequencing.

Insert Figure 3 about here

Validating hierarchical sequencing involves procedures to maintain quality control. Such a design incoporates these five basic components: learning hierarchy, task analysis, individual evaluation of

directions, empirical validation of program, and revision (Fig. 4). This model is unique because of the inclusion of two procedures to validate the sequence for conditions of learning and for efficency and effectiveness of instruction.

Insert Figure 4 about here

Learning Hierarchy

Sequencing behavior into a hierarchical order requires a detailed analysis of the objectives provided by the procedural steps of Merrill's paradigm (Fig. 2). Gagné, Markle, and Merrill have emphasized that the beginning of any design for programed instruction is the terminal behavior. The traditional form of a Mager-type (1962) behavior objective (i.e.; conditions, criteria, and behavior) does not refer to the condition of learning the student is to exhibit at the end of instruction.

The next procedure is to identify the enabling objectives (Fig. 4) of the terminal objective. What must a student do to perform the terminal objective? Following Merrill's paradigm, the first enabling objectives for problem solving would be the "analysis behavior" level (Fig. 2). This procedure continues until a sequence of enabling objectives are identified as prerequisites for the higher order behaviors. How far down the paradigm the designer goes is a qualitative decision at this point. The programer must estimate the S's competency level. In

elementary grades and industrial arts the objectives might include psychomotor behavior as part of the enabling objectives with the terminal behavior being complex cognitive. However, most instruction assumes relevant psychomotor behavior as prerequisite. Behavior which the learner is assumed to have prior to the new instruction must be specified. Figure 5 details the idea of assumed behaviors. These behaviors need in-depth analysis so that necessary conditions are not omitted from the instruction.

Insert Figure 5 about here

Instructional objectives can best be identified by the preparation of a flow diagram indicating the sequence of behaviors (Fig. 6). In this example for a seventh grade English course in sentence construction, the terminal objective is problem solving behavior. The student will be able to write a complete, accurate sentence when finished with the instruction. Only one principle from the analysis behavior level is illustrated with concepts. Memorization and psychomotor levels of behavior are assumed.

Insert Figure 6 about here

Task Analysis

After the objectives are identified and hierarchically charted, the next procedure is to validate the sequence by a task analysis. A task

analysis is a process by which the learning hierarchy is evaluated without instruction. An instrument is constructed so that each behavior on the hierarchical chart is tested not with one, but several, items. Accurate evaluation is essential for proper sequencing. The instrument should be administered to a random sample of subjects comprising those who can perform the behaviors indicated; those who can perform some, but not all, of the behaviors; and those who cannot perform any of the behaviors. Three different groups are essential because the first group measures the attainability of the terminal behavior; the second group measures the difficulty of the enabling objectives; and the third group represents samples from the population for whom the program is being developed. The evaluation of the behavioral objectives can be accomplished by using a task analysis grid.

The levels of behavior are divided into units, and are measured by appropriate items on the instrument, i. e., within each unit are items which test the identified behavior. The units are tested by criterion reference norms. If the subject obtains the criteria he is assumed to know the behavior. On the horizonatal axis of the task analysis grid (Fig. 7) are the behavioral objectives identified as the units representing the example from Figure 6. The terminal objectives, units 5 and 6, are to the right, and the enabling objectives, units 4, 3, 2 and 1 are in descending order to the left. The subjects criterion scores (X's), indicating passing, are arranged on the vertical axis according to the number of units passed.

Insert Figure 7 about here

This graph evaluated the sequence of the behavioral units. Units that are the most successfully passed should be the units on the lowest of behavior. In the example shown (Fig. 7), the classification behavior units are in proper order. However, problems are apparent in the analysis and problem solving units. Two possible errors could account for this situation. First, the test does not adequately measure the behavior. Or, secondly, the behaviors thought to be analysis and problem solving are not. Both errors could occur simultaneously, thus complicating analysis. In either case a reexamination of the behaviors and the test items is needed. A second task analysis should result in a graph resembling Figure 8. The task analysis procedure assures that the hierarchy for the instruction is empirically validated.

Insert Figure 8 about here

Insert Figure 9 about here

A logical hierarchy task analysis (Gagné, 1965, 1970) differs significantly. In the example shown (Fig. 7), units four and six would be considered out of sequence because too many subject reached criteria. Units three and five would be considered too low on the sequence because too few subjects reached criteria. On the basis of this analysis, the flow diagram would be rearranged (Fig. 9) to reflect the empirically derived sequence observed in the subjects measured by the test. Writing of the program would follow the sequence as illustrated in Figure 9; i.e., units 1, 2, 6, 4, 5, 3. This task analysis procedure is inappropriate because subject matter is analyzed instead of levels of behavior.

Individual Evaluation of Directions

Individual try-outs with those for whom the program is designed precedes an evaluation of the entire program in order that ambiguous directions are eliminated. Rewording, reorganizing, deletion, or addition, at this point can avoid complications when validating the entire program.

Empirical Validation of Program

Empirically validating the instructional program is the fifth step of quality control. This evaluation is concerned not only with the student reaching the terminal objective successfully but, also, with determining if the sequencing is effective and efficient. Group evaluation confirms the sequential structure by administration to a random sample of subjects. A common method of program validation (Fig. 10) involves contrasting the program with some other form of instruction. This model is inadequate, due to the undefined"other instruction." A priori assumption by programers is that a program can teach. A model of sequencing should be constructed to determine final internal validity of the program. A Full vs. Incomplete validation model (Fig. 11) meets this criteria. Any number of deletions and alternations can be constructed to analyze the sequence. The usual procedure is to test the sequence from one level of behavior to the next. As an example, the analysis behavior could be left out of the Full program to test the effect of instruction going from classification behavior to problem solving. This procedure differs

from the task analysis (only known behavior is measured), in that instructional strategies are included.

Insert Figure 10 about here

Insert Figure 11 about here

Revision of Program

Revision of the program is the concluding procedure of quality control. The program is revised according to the results in the above step and recycled until an acceptable criterion is reached. This recycling includes adjusting the hierarchical sequencing and/or deletion of unnecessary instruction. In addition to possible instructional changes, revision allows a reexamination of the procedural validity of the program.

Conclusion

Hierarchical sequencing based on instructional theories aids technologists in program development. Gagne and Merrill have helped in determining instructional objectives based on conditions of learning. On the other end of the continuum, abundant references have helped to evaluate test instruments. However, program development has not been subjected to minimum standards. As a result, problems from sequencing of conditions have produced learning errors. The quality control model discussed in this article is to facilitate development of effective instructional programs.

REFERENCES

Gagné, R. M. The conditions of learning. New York: Holt, Rhinehart, and Winston, 1965 (2nd Edition, 1970).

Gagné, R. M. Curriculum research and the promotion of learning. Perspectives in Curriculum evaluation. Chicago: Rand McNally, 1967.

Gagné, R. M. Learning hierarchies. Paper presented at the meeting of the American Psychological Association, San Francisco, August, 1968.

Mager, R. F. Preparing objectives for programed instruction. San Francisco: Fearon Pub., 1962.

Markle, S. M. Empirical testing of programs. In Lange, P. C. Programed Instruction: 66th Yearbook of the National Society for the Study of Education. pp. 104-140. (Text.), 1967.

Merrill, M. D. Necessary psychological conditinns for defining instructional outcomes. Educational Technology, 1970, in press.

Tennyson, R. D. and Merrill, M. D. Hierarchical models in the development of a theory of instruction: A comparison of Bloom, Gagne, and Merrill. Educational Technology, 1970, in press.

FOOTNOTE

1 For a complete analysis and comparison of Bloom, Gagné and Merrill see Tennyson and Merrill (1970).

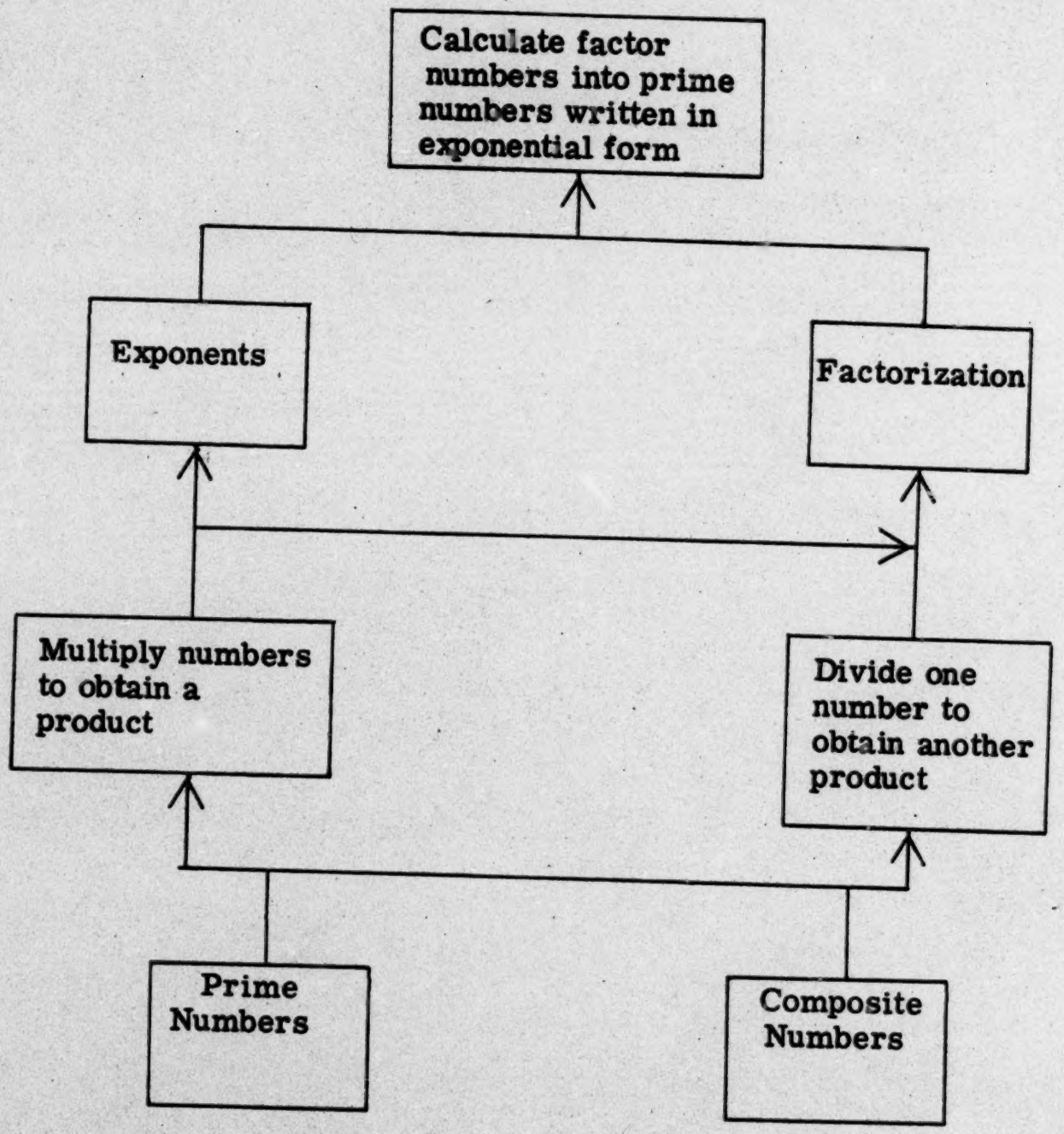
Calculate factor numbers into prime numbers written in exponential form
Exponents
Factorization
Multiply numbers to obtain a product
Divide one number to obtain another product
Prime Numbers
Composite Numbers

Figure 1: A logical hierarchy using Gagné's procedure.

Tennyson

	Emotional Behavior		
Pschomotor Behavior	Topographic Behavior	Chaining Behavior	Skilled Behavior
Memorization Behavior	Naming Behavior	Serial Behavior	Discrete Element Memorization Behavior
Complex Cognitive Behavior	Classification Behavior	Analysis Behavior	Problem Solving Behavior

Figure 2. Merrill's paradigm of instruction. The ten categories of learned behavior are hierarchically sequenced starting with topographic behavior, moving from left to right - top to bottom, to problem solving behavior. There is a relationship of behaviors vertically, i.e., the first column represents single responses, the second column represents a series of responses, and the third column represents a set of behaviors.

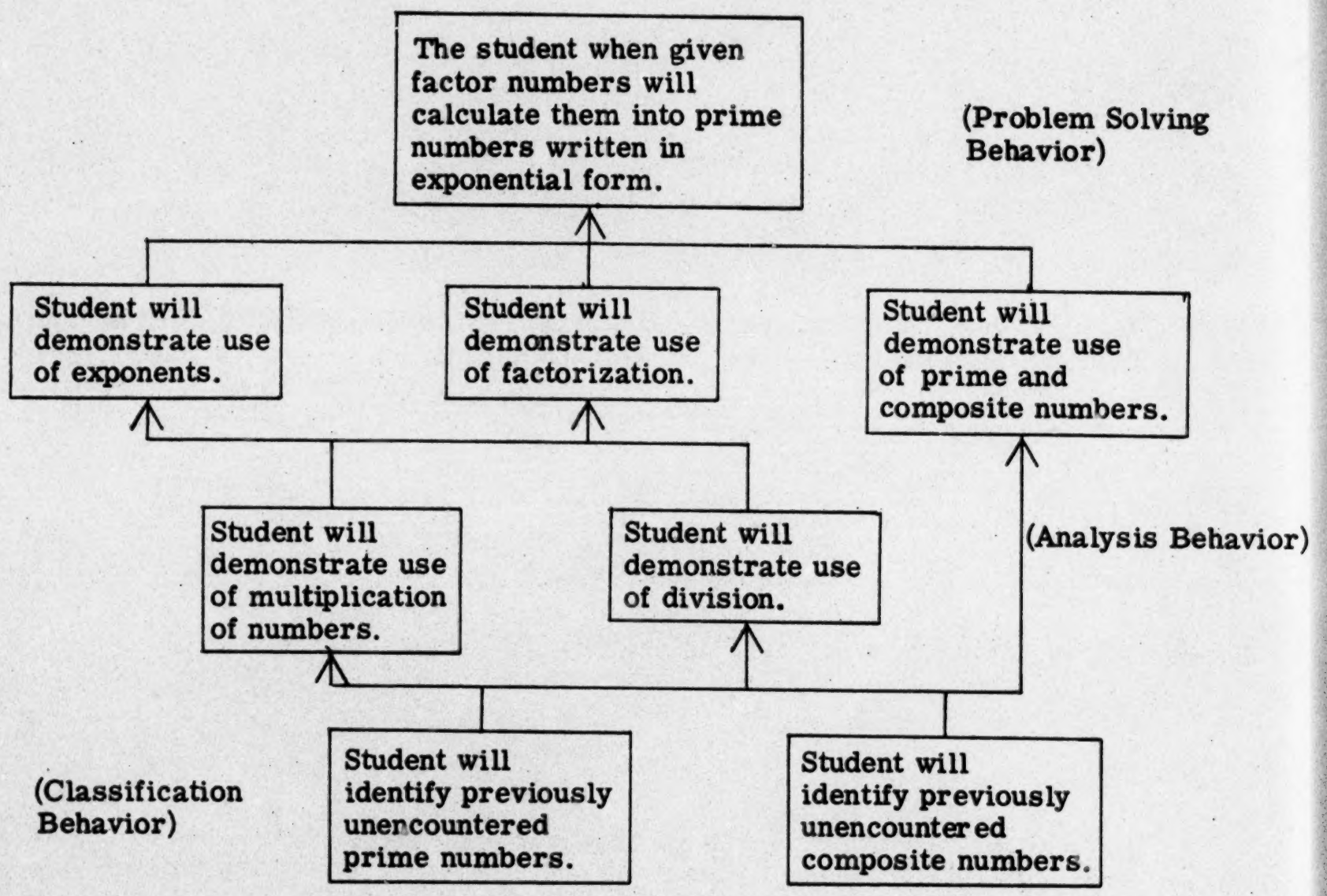
The student when given factor numbers will calculate them into prime numbers written in exponential form.
(Problem Solving Behavior)
Student will demonstrate use of exponents.
Student will demonstrate use of factorization.
Student will demonstrate use of prime and composite numbers.
Student will demonstrate use of multiplication of numbers.
Student will demonstrate use of division.
(Analysis Behavior)
(Classification Behavior)
Student will identify previously unencountered prime numbers.
Student will identify previously unencountered composite numbers.

Figure 3. A learning hierarchy based upon Merrill's levels of behavior.

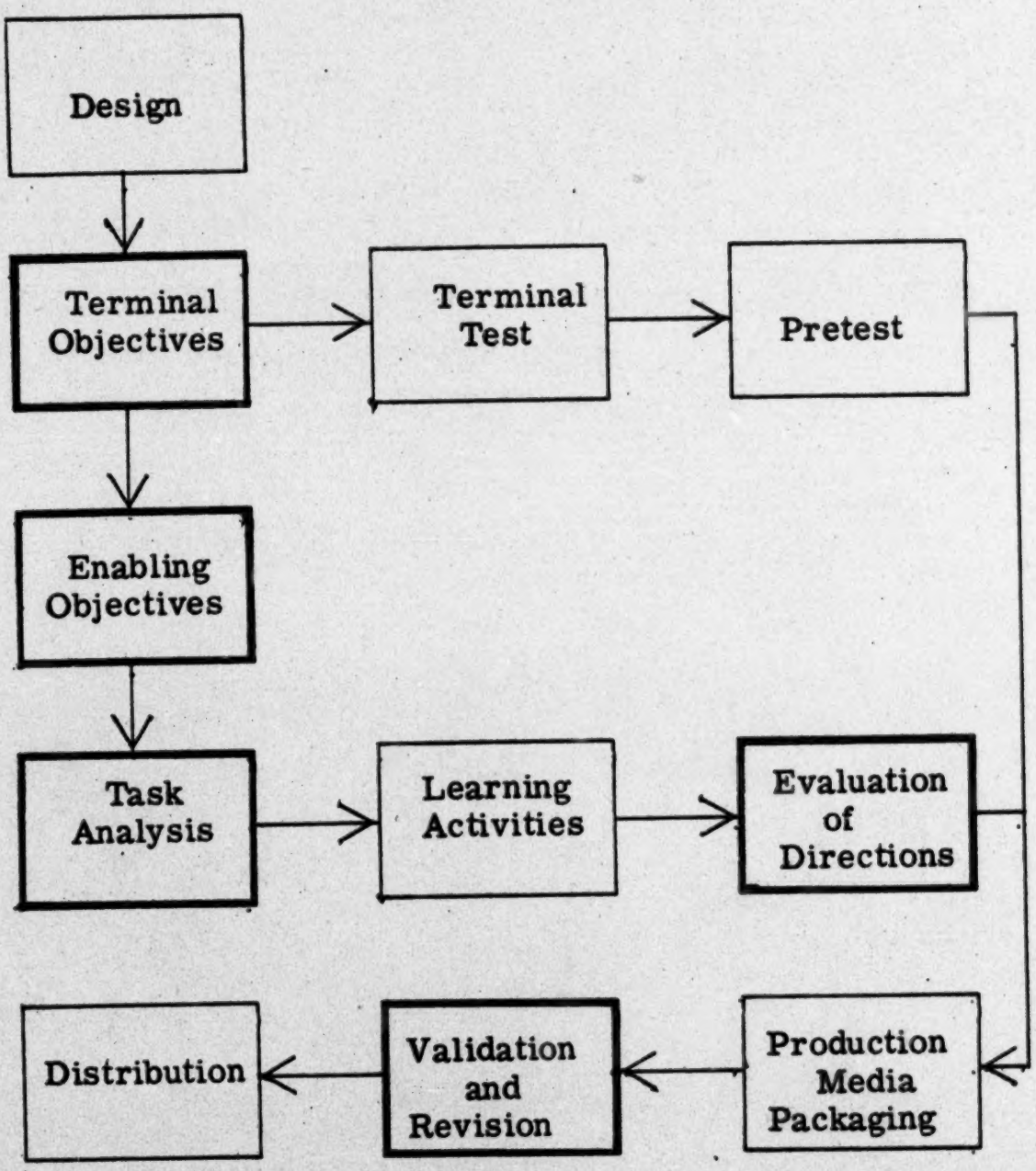

Figure 4. Flow chart of quality control in instructional design. The bold boxes represent the critical points of sequential validation.

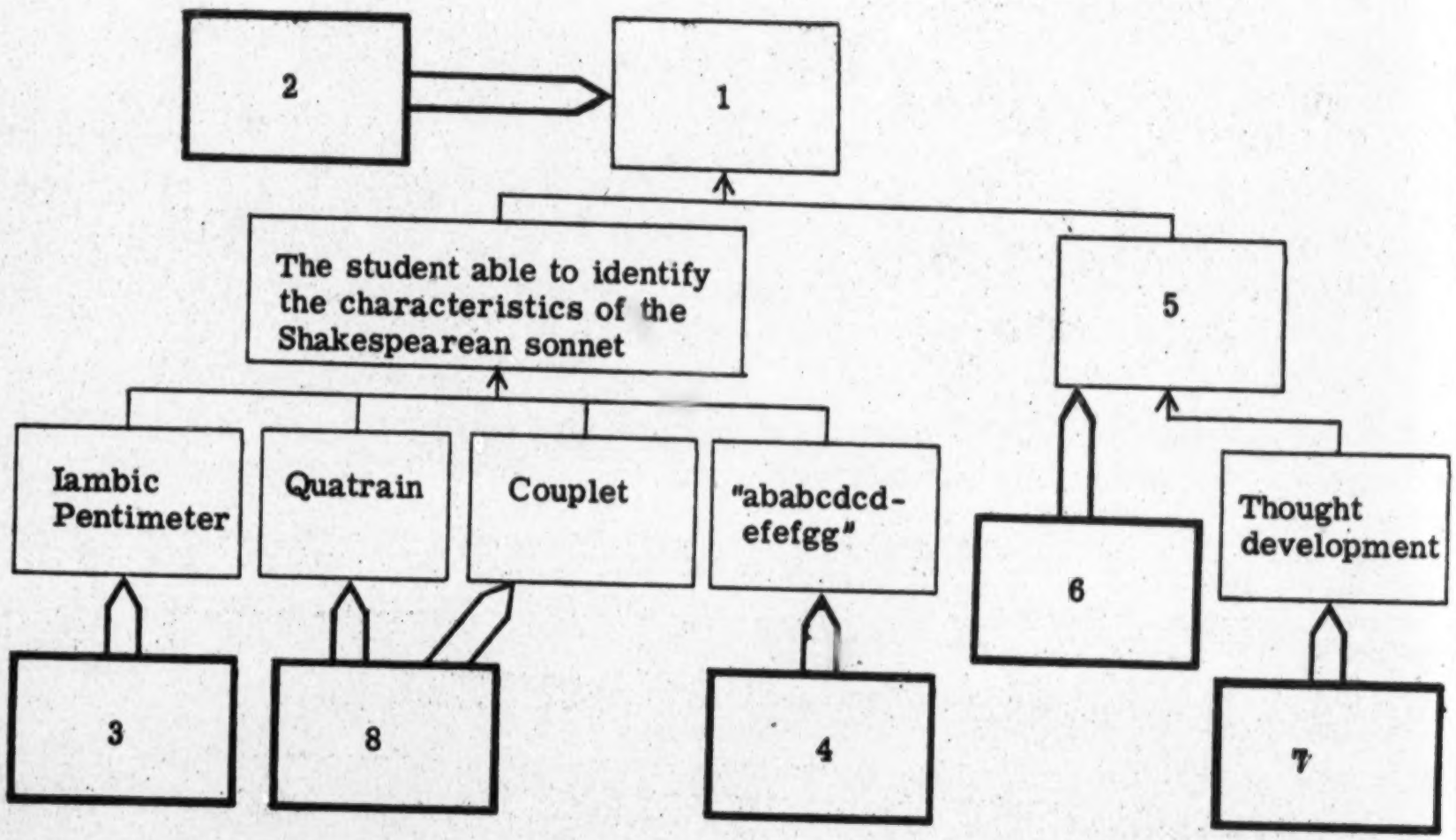

Figure 5. This flow chart illustrates the prerequisite assumptions (bold boxes) made for each condition of a proposed program on the Shakespearean sonnet.

Key: The above flow chart boxes are numbered and correspond to the numbered statements below.

1. The student, when presented a group of fourteen lines of poetry, each of which rhymes with one of the other lines, will construct a Shakespearean sonnet.

2. Assumed: The student knows:
   A. that the Shakespearean sonnet is named for William Shakespeare because he wrote many sonnets using this sonnet form; and, that the Shakespearean sonnet is also called the English sonnet.
   B. that there are two kinds of sonnets: the Shakespearean, or English sonnet and the Petrarchan sonnet, or Italian sonnet.
   C. that a Sonnet is a poem of fourteen lines.
   D. that a Poem is an arrangement of words in verse.
   E. that a Verse is a single line of poetry; a sequence of words (constituting a single line of poetry) arranged metrically.

3. Assumed: The student knows:
   A. that a Metrical Measurement, of the sequence of words which constitute a single line of poetry, is specifically named Meter.
   B. that Meter is a measured, patterned arrangement of syllables.
      a. that a Syllable is a word or part of a sounding of the voice.
      b. that a Foot is the basic unit of measurement; that the repetition of Feet produces a pattern that can be Metrically Measured; that the most common Feet in Fnglish poetry are:
         1. iamb (⏑ /)
         2. trochee (/ ⏑)
         3. anapest (⏑ ⏑ /)
         4. dactyl (/ ⏑ ⏑)
         5. spondee (//) ; that the number of Feet is counted and the following names are used:
            1. monometer (one foot)
            2. dimeter (two feet)
            3. trimeter (three feet)
            4. tetrameter (four feet)
            5. pentameter (five feet)
            6. hexameter (six feet)
   C. that Metrical Measureme nt is the measurement (number, extent) of the stressed, or accented (/) syllables and the unstressed, or unaccented (⏑) syllables.
      a. that the stressed syllables are indicated by the mark /.
      b. that the unstressed syllables are indicated by the mark ⏑.

4. Assumed: The student knows:
   A. that a Rhyme Scheme is a pattern of rhymes used in a poem, usually indicated by letters, such as: abab, or ccdd, etc.
   B. that the Rhyme is a recurrence of corresponding sounds, especially at the end of lines.

5. The student, when presented a Shakespearean sonnet will be able to identify the thought development of the sonnet and will be able to compare this thought development to the stanza form.

6. Assumed: The student knows:
   A. that the Shakespearean sonnet stanza form comprises:
      a. three quatrains
      b. one couplet
   B. that a Quatrain is a fourline stanza.
   C. that a Couplet is a twoline stanza.

7. Assumed: The student knows:
   that the Thought Development is not how you can interpret the ideas or thoughts presented in a poem, but <u>how</u> (some pattern, some sequence or order) the ideas or thoughts <u>are</u> presented.

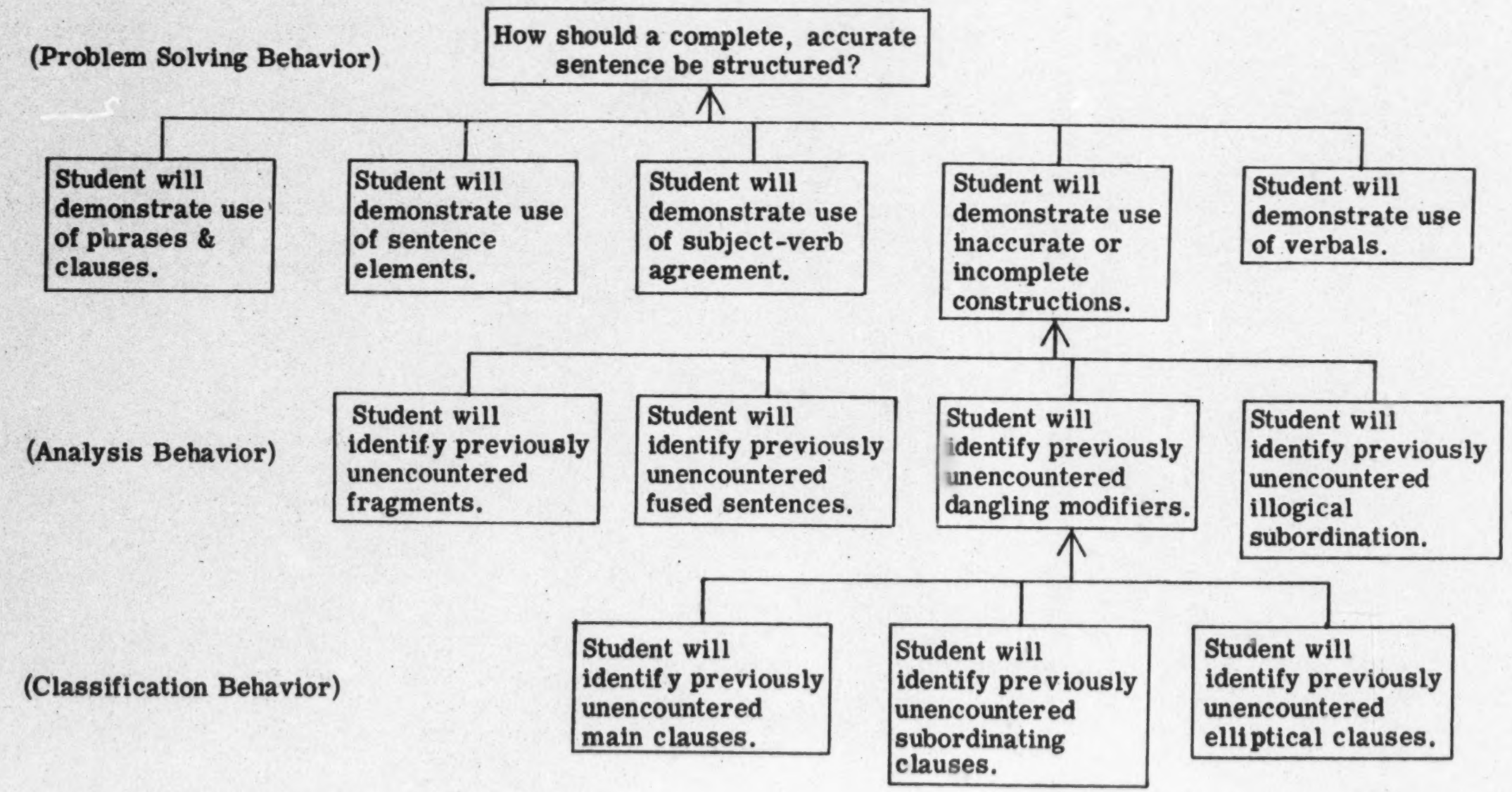
(Problem Solving Behavior)
How should a complete, accurate sentence be structured?
Student will demonstrate use of phrases & clauses.
Student will demonstrate use of sentence elements.
Student will demonstrate use of subject-verb agreement.
Student will demonstrate use inaccurate or incomplete constructions.
Student will demonstrate use of verbals.
(Analysis Behavior)
Student will identify previously unencountered fragments.
Student will identify previously unencountered fused sentences.
Student will identify previously unencountered dangling modifiers.
Student will identify previously unencountered illogical subordination.
(Classification Behavior)
Student will identify previously unencountered main clauses.
Student will identify previously unencountered subordinating clauses.
Student will identify previously unencountered elliptical clauses.

Figure 6. A sample flow diagram of a learning hierarchy prior to a task analysis. Only one sequence is shown to illustrate a hierarchy using Merrill's paradigm.

Behavioral Objective Units

Subject Scores	Classification 1	Classification 2	Analysis 3	Analysis 4	Problem Solving 5	Problem Solving 6
1	X	X	X	X	X	X
2	X	X		X	X	X
3	X	X	X	X	X	
4	X	X		X		X
5	X	X				X
6	X			X		X
7	X	X				
8	X					

Figure 7. A task analysis grid validating the hierarchical sequence on sentence construction from Figure 5. The "X's" represent subjects criterion scores on the vertical axis, indicating passing. The horizontal axis represents the terminal objective (problem solving) with enabling objectives (analysis and classification) in sequence to the left.

	Behavioral Objective Units					
	Classification		Analysis		Problem Solving	
	1	2	3	4	5	6
1	X	X	X	X	X	X
2	X	X	X	X	X	
3	X	X	X	X		
4	X	X	X			
5	X	X				
6	X	X				
7	X					
8	X					

Figure 8. A task analysis grid should look like this one following revision of the behaviors and test.

Logical Hierarchy Units

	1	2	4	6	5	3
1	X	X	X	X	X	X
2	X	X	X	X	X	
3	X	X	X		X	X
4	X	X	X	X		
5	X	X		X		
6	X		X	X		
7	X	X				
8	X					

Figure 9. In the usual task analysis only a reordering of the units would occur.

Pretest	Program	Posttest
Pretest	Other Instruction	Posttest

Figure 10. Comparative validation model.

Pretest	Program A	Posttest
Pretest	Program A-B	Posttest

Figure 11. Full vs. Incomplete validation model. To evaluate the final sequence of conditions the main program (A) is contrasted with a program that has had part (B) of the program removed.

WORKING PAPER REFERENCES

Clark, M. C. & Merrill, M. D. A cybernetic modification scheme for an instructional system. Educational Technology, 1970, in press.

Merrill, M. D. Necessary psychological conditions for defining instructional outcomes. Educational Technology, 1970, in press.

Merrill, M. D. Organizing for instructional system development. Unpublished manuscript. Department of Instructional Research and Development, Brigham Young University, 1970.

Merrill, M. D. Paradigms for psychomotor instruction. Unpublished manuscript. Department of Instructional Research and Development, Brigham Young University, 1970.

Merrill, M. D. & Harrison, G. V. Instructional research and development at Brigham Young University: A statement of philosophy and intent. Unpublished manuscript. Department of Instructional Research and Development, Brigham Young University, 1970.

Orey, J. & Others. Faculty guide to the department of instructional research and development. Unpublished manuscript. Department of Instructional Research and Development, Brigham Young University, 1970.

Tennyson, R. D. A critical review of experimental methodology in instructional sequencing. AV Communications Review, 1970, in press.

Tennyson, R. D. & Boutwell, R. C. A Quality Control Design for Validating Hierarchical Sequencing of Programed Instruction. NSPI Journal, 1970, in press.

Tennyson, R. D. & Merrill, M. D. Hierarchical models in the development of a theory of instruction: A comparison of Bloom, Gagne, and Merrill. Educational Technology, 1970, in press.

Tennyson, R. D. & Woolley, F. R., & Crosby L. J. The effect of interaction of anxiety with performance on two levels of task difficulty. Journal of Educational Psychology, 1970, in press.

Tennyson, R. D. & Woolley, F. R. Exemplar and nonexemplar variables which produce correct concept classification behavior and specified classification errors. Journal of Educational Psychology, 1970, in press.

Woolley, F. R. & Tennyson, R. D. Conceptual models of classification behavior. Educational Technology, 1970, in press.